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010092182 **Image available**
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Related WPI Acc No: 98-017918
XRPX Acc No: N94-281997
Engine noise control appts. for vehicle - includes CPU which modifies phase and amplitude of periodic signal w.r.t engine rotation reference signal based on rotation pulse signal and control signal
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Number of Countries: 017 Number of Patents: 002
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Patent No	Kind	Date	Applicat No	Kind	Date	Main IPC	Week
EP 625773	A2	19941123	EP 94107760	A	19940519	G10K-011/16	199445 B
EP 625773	A3	19951018					199616

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2531023; GB 2254979
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NL PT SE

Abstract (Basic): EP 625773 A
A sensor (5) detects an engine rotating speed. A waveform generator (46) converts a rotation pulse signal to a periodic signal with frequency a predetermined multiple of detected speed. The output of an air flow meter (3) is passed through a bandpass filter (41). A rectifier (42) generates a control signal which is an average of ac component of the output. A processor (44), referring to a stored map, modifies phase and amplitude of the periodic signal according to a reference outputting driving signals operating speakers (6A, 6B).
ADVANTAGE - Reduces wide range of engine noise.
Dwg.1/11
Title Terms: ENGINE; NOISE; CONTROL; APPARATUS; VEHICLE; CPU; MODIFIED;
PHASE; AMPLITUDE; PERIODIC; SIGNAL; ENGINE; ROTATING; REFERENCE;
SIGNAL;
BASED; ROTATING; PULSE; SIGNAL; CONTROL; SIGNAL
Derwent Class: P86; T01; W04; X22
International Patent Class (Main): G10K-011/16
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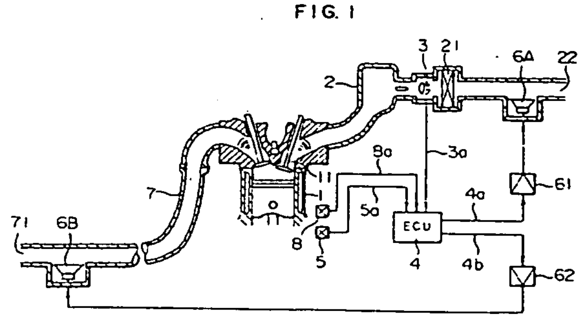
(54) Engine noise control apparatus.

(57) An engine noise control apparatus which is capable of effectively reducing or waveform-reshaping a wide range of engine noise. The apparatus has an engine rotating speed sensor (5) for detecting an engine rotating speed and a waveform generator circuit (46) for converting a rotation pulse signal to a periodic signal having a frequency which is a predetermined multiple of the detected engine rotating speed. The output of an air flow meter (3) is passed through a bandpass filter (41) and a rectifier circuit (42) to generate a control signal which is an average value of alternating current components of the output. A CPU (44), with reference to a map previously stored in a memory (45), modifies the phase and amplitude of the periodic signal with respect to an engine rotation reference signal based on the rotation pulse signal and the control signal, and outputs the modified signal as driving signals to operate speakers (6A, 6B) disposed in an intake tube and an exhaust tube for reducing noise.

FIG. 1



EP 0 625 773 A2

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an engine noise control apparatus, and more particularly to a noise control apparatus which generates control sound in order to cancel noise or convert the noise into a favorable tone.

Description of the Related Art

As noise sources of a vehicle, intake sound and exhaust sound may be pointed out. Conventionally, a variety of resonators have been used to reduce intake sound, while mufflers have been used to reduce exhaust sound.

However, although these conventional noise control apparatuses mainly based on the resonance effect are effective in reducing limited noise near a resonance frequency, they do not provide sufficient noise preventing effects for engine noise which lies over a relatively wide frequency range.

SUMMARY OF THE INVENTION

The present invention has been made to solve the above-mentioned problem, and its object is to provide an engine noise control apparatus which is capable of effectively reducing a wide range of engine noise or converting the waveform of such engine noise.

According to the present invention as shown in Fig. 11, there is provided an engine noise control apparatus comprising means for detecting an engine rotating speed; periodic signal generation means for generating an oscillation signal having a frequency which is a predetermined multiple of the detected engine rotating speed; means for detecting pulsation components of intake air supplied to the engine; means for generating a control signal in accordance with the magnitude of the detected pulsation components of the intake air supplied to the engine; means for detecting a reference position in rotation of the engine and for outputting a reference position signal; means for modulating the phase and amplitude of the oscillation signal with respect to a reference position signal based on the engine rotating speed and the control signal, and outputting the modulated oscillation signal as a driving signal; and sound generation means disposed in at least one of intake sound and exhaust sound propagation paths of the engine for generating control sound in accordance with the driving signal.

A main frequency component causing engine intake sound and exhaust sound is a frequency which is a predetermined multiple (order) of an engine rotating speed which is defined by the number of cylinders and so on. The periodic signal generation means multiplies the engine rotating speed by a predetermined number previously determined from the number of cylinders and so on, to generate the periodic signal at the same frequency as that of problematic noise, i.e., the order of the engine rotating speed.

The periodic signal is properly modified to modulate its amplitude and phase with respect to the reference position signal based on the engine rotating speed and the control signal, and outputted to the sound generation means as a driving signal. The sound generation means, upon receiving the driving signal, generates control sound in accordance with the driving signal to cancel or reduce propagating engine intake sound and so on or convert the sound into a favorable sound waveform.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the whole configuration of a noise control apparatus;
Fig. 2 is a block diagram showing the configuration of an electronic control unit;
Fig. 3 is a block diagram showing the configuration of a waveform generator circuit;
Fig. 4 is a waveform chart showing an output signal of an air flow meter;
Fig. 5 is a graph showing changes in intake sound pressure with respect to the time;
Fig. 6 is a characteristic graph showing changes in the output of the air flow meter with respect to the engine rotating speed;
Fig. 7 is a waveform chart showing how a control signal is produced;
Fig. 8 is a diagram showing a concept of a map;
Fig. 9 is a waveform chart showing an output of an air flow meter in another embodiment of the present invention;
Fig. 10 is a graph showing a control range in a further embodiment of the present invention; and
Fig. 11 is a block diagram showing a general configuration of an engine noise control apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[First Embodiment]

Fig. 1 shows the configuration of an engine noise control apparatus. An air flow meter 3 of a known structure using a hot-wire is disposed in an intake tube extending from an intake port 11 of an engine cylinder 1 at a location downstream of an air cleaner 21. An output signal 3a of the air flow

meter 3 is inputted to an electronic control unit (ECU) 4. This ECU 4 is also supplied with a rotation pulse signal 5a corresponding to an engine rotating speed from a known engine rotating speed sensor 5 as well as a reference position signal 8a corresponding to an explosion timing of the engine from a known engine rotation reference position sensor 8.

The ECU 4 not only controls an electronic fuel injection (EFI) and so on, but also generates driving signals 4a, 4b from the signals 3a, 5a, 8a, for damping intake sound and exhaust sound by a procedure, later described. These driving signals 4a, 4b are respectively outputted through amplifiers 61, 62 to a speaker 6A which is placed in the intake tube 2 near an intake opening 22 for serving as an actuator for controlling intake sound and a speaker 6B which is placed in an exhaust tube 7 near an exhaust opening 71 for serving as an actuator for controlling exhaust sound.

Fig. 2 shows the configuration of the ECU 4. The signal 3a generated by the air flow meter 3 is inputted to a bandpass filter 41 which only extracts alternating current components which are supplied to a CPU 44 through a rectifier circuit 42 as a control signal 42a. The signal 3a is composed of a direct current component proportional to an intake air amount and alternating current components P proportional to intake air pulsation which are superposed with the direct current component. It can be seen from Fig. 5 that changes in a main component of the alternating current components P along the time is fairly coincident with changes in sound pressure Pa of intake sound. Also, as shown in Fig. 6, changes in both the alternating current component level and the sound pressure level with respect to the engine rotating speed exhibit coincident characteristics.

The alternating current components of the signal 3a from the air flow meter 3 include superposed high frequency components as shown in Fig. 7(a) which, however, are removed when the signal 3a passes through the bandpass filter 41, thereby leaving only the main component (Fig. 7-(b)) which is defined by an order corresponding to the number of engine cylinders and the number of cycles (for example, the order is two for a four-cycle four-cylinder engine). The main component is full-wave rectified by a rectifier circuit 42 at the next stage (Fig. 7(c)), and then smoothed (Fig. 7-(d)) to be outputted as the control signal 42a indicative of a mean value of the alternating current components. This control signal 42a corresponds to intake air pulsation, i.e., the magnitude of intake noise. It will be understood that since exhaust noise generated due to exhaust gas pulsation exhibits a behavior similar to the intake noise, the control signal 42a also corresponds to the magnitude of the exhaust noise.

The rotation pulse signal 5a from the engine rotating speed sensor 5 is inputted to a waveform reshaping circuit 43 (Fig. 2) and reshaped to be a rectangular wave at a TTL level which is supplied to the CPU 44 and a waveform generator circuit 46. The waveform generator circuit 46 is configured as shown in Fig. 3, and comprises a multiplication circuit 461, a low-pass filter 462, a phase control circuit 463, and an amplitude control circuit 464, all of which are serially connected in this order.

The rotation pulse signal 43a reshaped by the waveform reshaping circuit 43 is supplied to the multiplication circuit 461. This multiplication circuit 461, in response to a command from the CPU 44, generates a pulse signal at a frequency which is a predetermined multiple of the frequency of the signal 43a. In this manner, the multiplication circuit 461 generates a periodic pulse signal 461a which has the same frequency, for example, as the main component of the alternating current components included in the signal 3a from the air flow meter 3, i.e., the frequency of noise.

The low pass filter 462 at the subsequent stage changes a cut-off frequency thereof by a command from the CPU 44, such that a source driving signal 462a in a substantially sine wave shape near the fundamental frequency is extracted from the periodic signal 461a including harmonic components and outputted from the low pass filter 462.

The source driving signal 462a, while passing through the phase control circuit 463 and the amplitude control circuit 464, is modified to modulate its phase and amplitude with respect to the reference position signal 8a by predetermined amounts, based on a command from the CPU 44. The modifying amounts of the phase and amplitude have previously been stored in a memory 45 in the form of maps, some examples of which are shown in Fig. 8. As can be seen from Fig. 8, a phase control amount and an amplitude control amount for providing favorable sound damping effects have been empirically determined and set for each combination of predetermined values of the control signal 42a generated from the air flow meter output 3a and the rotation pulse signal 43a indicative of the engine rotating speed (T1, T2, ..., N1, N2, ...).

Though illustration is omitted, a plurality of maps 451, 452, 453 are provided corresponding to the respective orders of the engine rotating speed as required, and two sets of these maps are prepared for intake sound and exhaust sound.

The source driving signal 462a having its phase and amplitude modified by predetermined amounts by the phase control circuit 463 (Fig. 3) and the amplitude control circuit 464 (Fig. 3) are outputted to intake sound and exhaust sound control speakers 6A, 6B through the respective amplifi-

ers 61, 62 as the driving signals 4a, 4b. Control sound is generated into the intake tube 2 and the exhaust tube 7 respectively from the speakers 6A, 6B in response to the driving signals. Thus, the control sound from the intake sound control speaker 6A and the control sound from the exhaust sound control speaker 6B, having substantially the same amplitudes and phases different by substantially 1801 from each other, cancel or reduce intake sound and exhaust sound, respectively.

In the foregoing manner, the magnitude of the intake air pulsation is predicted from the alternating current components of the output from the air flow meter 3, and the control sound for damping is generated on the basis of the alternating current components and the engine rotating speed, so that intake sound and exhaust sound over wide frequency ranges can be favorably damped promptly in response to even rapid acceleration of the vehicle or the like.

[Second Embodiment]

As shown in Fig. 9, the alternating current components in the output from the air flow meter 3 may relatively largely vary at peak values P1, P1', P2, P2'.... for respective cylinders #1, #2, #3, #4 (Fig. 9 shows the case of a four-cylinder engine by way of example). In this event, the peak values for the respective cylinders are averaged in the CPU 44 to derive an average value instead of reshaping the alternating current components by the reshaping circuit 43.

If the peak values for the respective cylinders do not vary so much, a value for any of the cylinders may be taken as being representative of an average value.

Alternatively, instead of calculating an average value of the alternating components for the four cylinders, the noise control may be performed for each cylinder in accordance with the magnitude of pulsation components for each cylinder.

[Third Embodiment]

Normally, intake and exhaust noise increases as the throttle valve aperture is larger as shown in Fig. 10. Therefore, the sound damping control may be performed only at the throttle value aperture equal to q1 or more, where the noise causes a problem.

[Fourth Embodiment]

During acceleration of a vehicle, the magnitude of detected pulsation components may exhibit a value smaller than a sound pressure of actual noise due to a response delay of the air flow meter. To solve this problem, when acceleration of the vehicle is detected, the control signal 42a generated from the reshaping circuit 42 may be amplified.

[Fifth Embodiment]

Even with the same type of engines, errors may occur in the noise control based on previously set map data, due to the difference in layout of the intake system and aging change. Therefore, in consideration of the fact that the pulsation components or alternating components in the output of the air flow meter correspond to an intake sound pressure, learning feedback control may be performed in order to correct map data such that the amplitude control amount is corrected by the magnitude of pulsating intake air, and the phase control amount is corrected by a deviated time of the timing of a peak or bottom of the pulsation components from the timing of the reference position signal. By thus correcting the map data in accordance with the pulsating intake air supplied to the engine to be actually controlled, better noise control can be provided.

Incidentally, since engine noise causes a problem particularly when an engine load is large, the noise control may be started when the alternating current components in the output from the air flow meter show a predetermined value or more.

In the respective embodiments, when an intake tube pressure sensor is provided in place of the air flow meter for EFI, alternating current components in a signal generated by the pressure sensor may also be used, resulting in producing similar effects.

It should be noted that the control sound does not necessarily have a waveform for cancelling or reducing noise, but may have a waveform which modifies noise to a favorable tone.

While the foregoing embodiments have been described for the case where both intake and exhaust noise should be reduced, either of them may be reduced.

Also, in place of speakers, other sound generators using a piezoelectric plate or the like may be used.

As described above, according to the noise control apparatus of the present invention, since pulsation components of engine intake air are detected, and control sound is generated on the basis of the pulsation components and the engine rotating speed, a wide range of intake and exhaust noise can be controlled with a good responsibility.

In the above embodiments, the control sound is generated by detecting an engine load or the intake air supplied to the engine in addition to the engine rotating speed, however, the control sound may be generated on the basis of only the engine rotating speed.

An engine noise control apparatus which is capable of effectively reducing or waveform-reshaping a wide range of engine noise. The apparatus has an engine rotating speed sensor (5) for detecting an engine rotating speed and a waveform generator circuit (46) for converting a rotation pulse signal to a periodic signal having a frequency which is a predetermined multiple of the detected engine rotating speed. The output of an air flow meter (3) is passed through a bandpass filter (41) and a rectifier circuit (42) to generate a control signal which is an average value of alternating current components of the output. A CPU (44), with reference to a map previously stored in a memory (45), modifies the phase and amplitude of the periodic signal with respect to an engine rotation reference signal based on the rotation pulse signal and the control signal, and outputs the modified signal as driving signals to operate speakers (6A, 6B) disposed in an intake tube and an exhaust tube for reducing noise.

Claims

1. An intake sound control apparatus comprising:

   intake sound information detecting means (5, 43) for sampling intake sound information due to the drive of an engine, said intake sound information detection means having engine rotating speed detection means for detecting a rotating speed of said engine;

   signal generation means (44) for generating a signal having a frequency corresponding to a desired ratio of orders based on the intake sound information sampled by said intake sound information sampling means;

   memory means (45) including a control map for storing data of phases and amplitudes, said phases and said amplitudes corresponding to an engine rotating speed;

   signal modifying means (46) for phase-controlling and amplitude-controlling the signal generated by said signal generation means in accordance with a phase and an amplitude read from the control map using the detected engine rotating speed; and

   control sound generation means (61, 62, 6A, 6B) for generating control sound in accordance with the signal of said signal modifying means and for supplying said control sound to a propagation path of the intake sound.

2. An intake sound control apparatus according to Claim 1 wherein said rotating speed detecting means is a rotation speed sensor for generating a signal representing a rotation speed of a rotary shaft of the engine, and said signal generation means includes a multiplication circuit for multiplying a frequency of the signal from said rotating speed sensor and a low-pass filter for eliminating harmonics of the multiplied signal and for extracting only a first-order component corresponding to the desired ratio of orders.

3. An intake sound control apparatus according to Claim 1 wherein said intake sound information detection means further having an engine load detection means.

4. An intake sound control apparatus according to Claim 1 wherein said signal modifying means determines a change in the rotating speed of the engine and performs said phase-controlling and said amplitude controlling corresponding to the change in rotating speed when the change in rotating speed exceeds a predetermined level.

5. An intake sound control apparatus according to Claim 1 wherein said signal generation means uses a ratio of orders associated with the rotating speed of the engine.

6. An intake sound control apparatus according to Claim 1 wherein said signal modifying means controls by using phase data and amplitude data of a specified ratio of orders for rotating speeds.

7. A sound control apparatus comprising:

   sound information detection means (5, 43) for sampling sound information due to the drive of an engine, said sound information detecting means having engine rotating speed detecting means for detecting a rotating speed of said engine;

   signal generation means (44) for generating a signal having a frequency corresponding to a desired ratio of orders based on the sound information sampled by said sound information sampling means;

   memory means (45) including a control map for storing data of phases and amplitudes, said phases and said amplitudes corresponding to an engine rotating speed;

   signal modifying means (46) for phase-controlling and amplitude-controlling the signal generated by said signal generation means in accordance with a phase and an amplitude read from the control map using the detected engine rotating speed; and

   control sound generation means (61, 62, 6A, 6B) for generating control sound in accordance with the signal of said signal modifying means and for supplying said control sound to

a propagation path of the sound.

8. A sound control apparatus according to Claim 7 wherein said engine rotating speed detecting means is a rotation speed sensor for generating a signal representing a rotation speed of a rotary shaft of the engine, and said signal generation means includes a multiplication circuit for multiplying a frequency of the signal from said rotating speed sensor and a low-pass filter for eliminating harmonics of the multiplied signal and for extracting only a first-order component corresponding to the desired ratio of orders.

9. A sound control apparatus according to Claim 7 wherein said signal modifying means determines a change in the rotating speed of the engine and performs said phase-controlling and said amplitude-controlling corresponding to the change in rotating speed when the change in rotating speed exceeds a predetermined level.

10. A sound control apparatus according to Claim 7 wherein said signal generation means uses a ratio of orders associated with the rotating speed of the engine.

11. A sound control apparatus according to Claim 7 wherein said signal modifying means controls by using phase data and amplitude data of a specified ratio of orders for rotating speeds.

12. A sound control apparatus according to Claim 7 wherein said sound information detecting means further having an engine load detecting means.

13. A sound control apparatus comprising:

engine rotating speed detecting means (5, 43) for detecting a rotating speed of said engine;

engine load detecting means (3, 41, 42) for detecting a load of said engine;

signal generation means (44) for generating a signal having a frequency corresponding to a desired ratio of orders based on the sound information sampled by said engine rotating speed detecting means and said engine load detecting means;

memory means (45) including a control map for storing data of phases and amplitudes, said phases and said amplitudes corresponding to an engine rotating speed and an engine load;

signal modifying means (46) for phase-controlling and amplitude-controlling the signal generated by said signal generation means in accordance with a phase and an amplitude read from the control map using the detected engine rotating speed and the detected engine load; and

control sound generation means (61, 62, 6A, 6B) for generating control sound in accordance with the signal of said signal modifying means and for supplying said control sound to a propagation path of the sound.

14. An engine noise control apparatus comprising:

rotating speed detection means (5, 43) for detecting a rotating speed of an engine;

signal generation means (44) for generating an oscillation signal having a frequency which is a predetermined multiple of the detected rotating speed of said engine;

intake signal detection means (3) for detecting pulsation components of intake air supplied to said engine;

control signal producing means (41, 42) for producing a control signal in accordance with a signal generated by said intake signal detection means;

position detection means (8) for detecting a reference position in rotation of said engine and for outputting a reference position signal;

signal modifying means (45, 46) for modifying a phase and an amplitude of said signal generation means with respect to a signal of said position detection means on the basis of a signal of said rotating speed detection means and a signal of said control signal producing means; and

control sound generation means (61, 62, 6A, 6B) disposed in at least one of intake sound and exhaust sound propagation paths of said engine and for generating a control sound in accordance with a signal of said signal modifying means.

15. An engine noise control apparatus according to claim 14, wherein said intake signal detection means (3) detects the pulsation components of intake air supplied to said engine by use of an air flow meter disposed in a midway of an intake path of said engine.

16. An engine noise control apparatus according to claim 14, wherein said control signal producing means (41, 42) takes an average of peak values of said pulsation components for cylinders of said engine in each predetermined period to generate said control signal for each of cylinders of said engine, and said modifying means modifies said oscillation signal on the

basis of said each a signal of said control signal producing means.

17. An engine noise control apparatus according to claim 14, wherein said modifying means (45, 46) outputs said driving signal when said control signal is larger than a predetermined value.

18. An engine noise control apparatus according to claim 14, wherein said detection means (3) detects the pulsation components of intake air supplied to said engine by use of a pressure sensor disposed in a midway of an intake path of said engine.

19. An engine noise control apparatus according to claim 14, wherein said modifying means (45, 46) modifies signals for performing phase control with respect to a rotation reference position of said internal combustion engine.

20. A sound control apparatus comprising:
rotating speed detection means (5, 43) for detecting a rotating speed of an internal combustion engine;
intake signal detection means (3) for detecting pulsation components of intake air supplied to said internal combustion engine;
control signal producing means (41, 42) for producing a control signal corresponding to a signal generated by said intake signal detection means;
signal modifying means (44, 45, 46) for modifying signals for performing phase control and amplitude control from the signals generated by said rotating speed detecting means and by said control signal producing means; and
control sound generation means (61, 62, 6A, 6B) for generating control sound in accordance with said signal of said signal modifying means and for supplying said control sound to a propagation path of the sound.

21. A sound control apparatus according to Claim 20, wherein said intake signal detection means detects the pulsation components of intake air supplied to said engine by use of an air flow meter disposed in a midway of an intake path of said engine.

22. A sound control apparatus according to Claim 20, wherein said intake signal detection means detects the pulsation components of intake air supplied to said engine by use of a pressure sensor disposed in a midway of an intake path of said engine.

23. A sound control apparatus according to Claim 20, wherein said signal modifying means modifies signals for performing phase control with respect to a rotation reference position of said internal combustion engine.

24. A sound control apparatus comprising:
engine rotating speed detection means (5, 43) for detecting a rotating speed of an internal combustion engine;
engine load detection means (3, 41, 42) for detecting engine load by detecting pulsation components of intake air supplied to said internal combustion engine;
signal generation means (44) for generating a signal having a frequency corresponding to a desired ratio of orders based on the sound information sampled by said engine rotating speed detecting means and said engine load detecting means;
memory means (45) including a control map for storing data of phases and amplitudes, said phases and said amplitudes corresponding to an engine rotating speed and an engine load;
signal modifying means (46) for phase-controlling and amplitude-controlling the signal generated by said signal generation means in accordance with a phase and an amplitude read from the control map using the detected engine rotating speed and the detected engine load; and
control sound generation means (61, 62, 6A, 6B) for generating control sound in accordance with said signal of said signal modifying means and for supplying said control sound to a propagation path of the sound.

25. A sound control apparatus according to Claim 24, wherein said engine load detection means has intake signal detecting means for detecting pulsation components of intake air intake supplied to said internal combustion engine and engine load signal producing means for producing a engine load signal corresponding to a signal generated by said intake signal detection means.

26. A sound control apparatus according to Claim 25, wherein said intake signal detection means detects the pulsation components of intake air supplied to said engine by use of an air flow meter disposed in a midway of an intake path of said engine.

27. A sound control apparatus according to Claim 25, wherein said intake signal detection means detects the pulsation components of intake air

supplied to said engine by use of a pressure sensor disposed in a midway of an intake path of said engine.

28. A sound control apparatus according to Claim 24, wherein said signal modifying means modifies signals for performing phase control with respect to a rotation reference position of said internal combustion engine..

FIG. 1

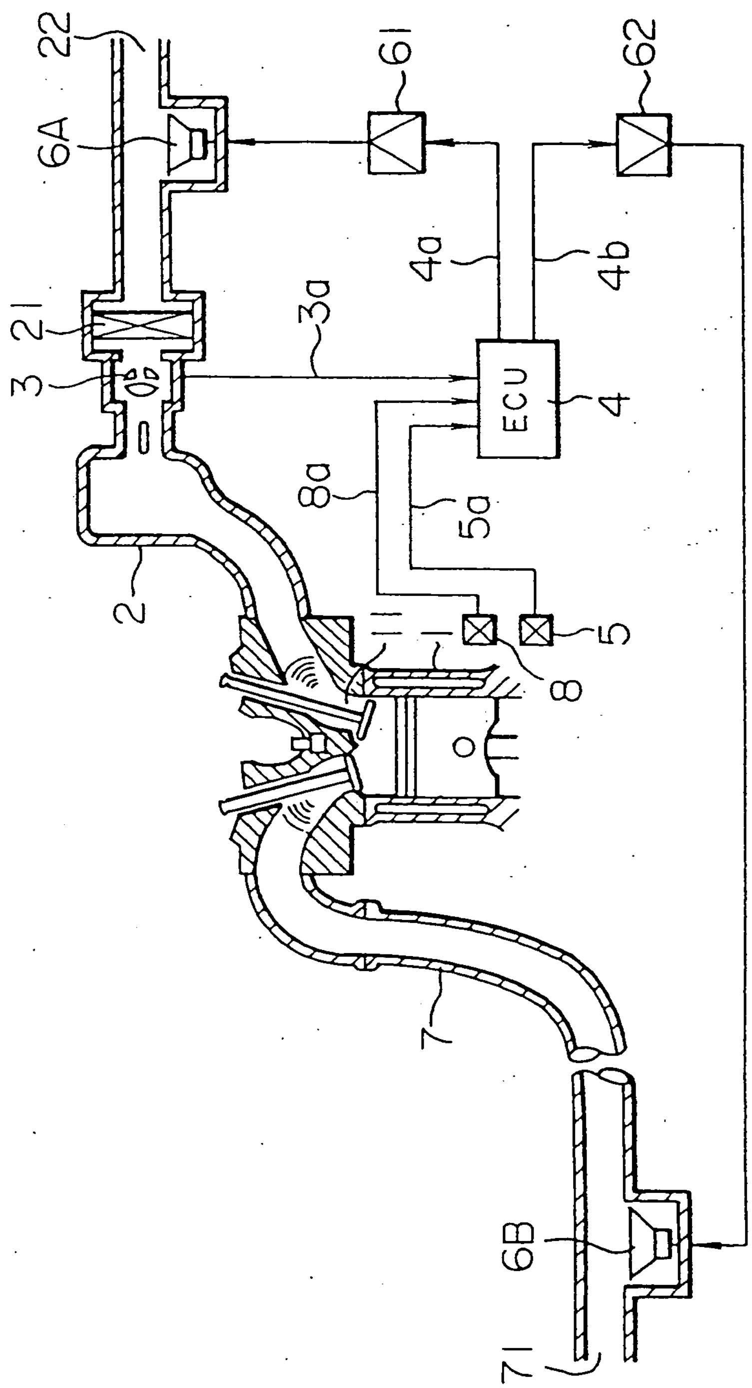


FIG. 2

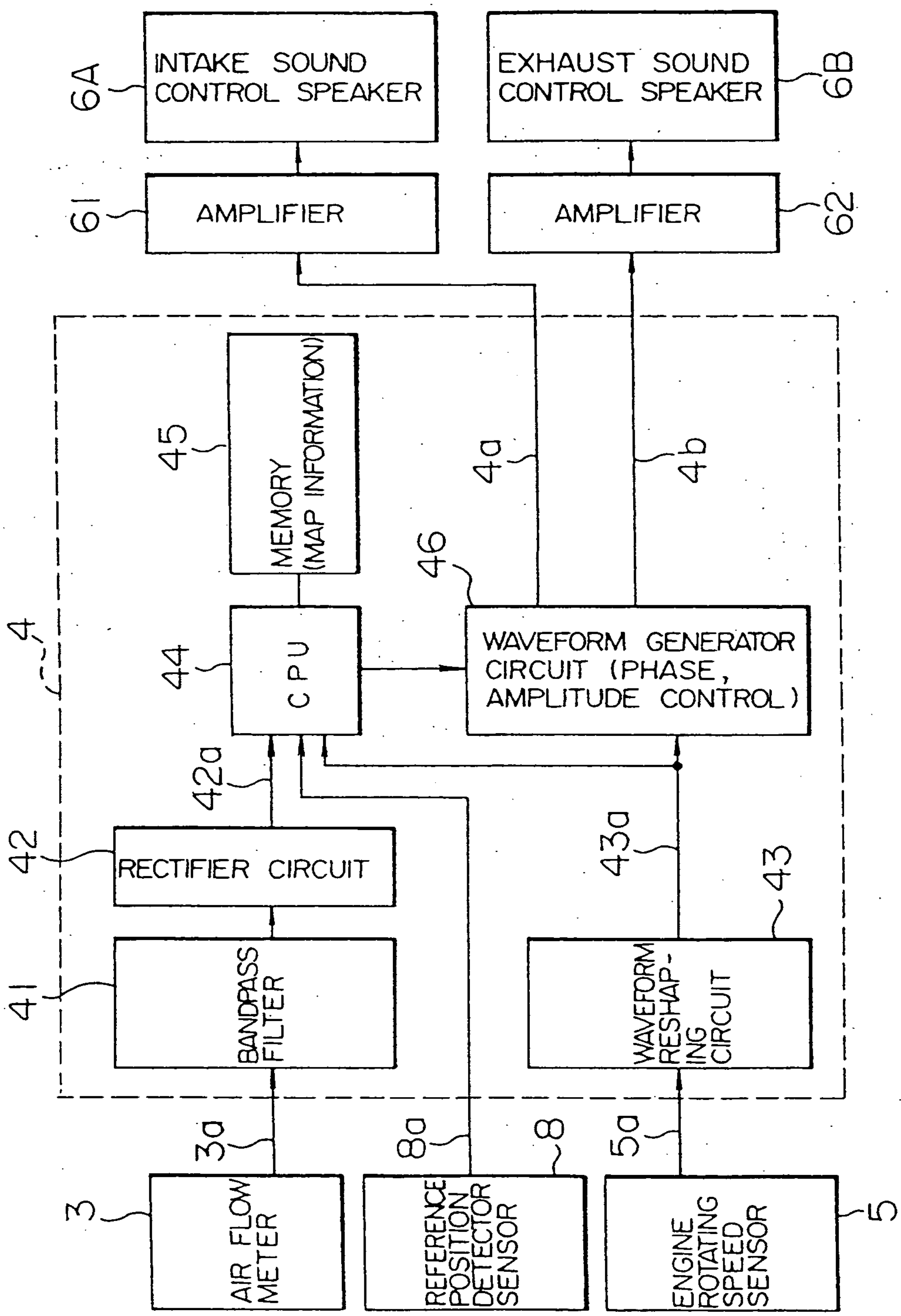

INTAKE SOUND CONTROL SPEAKER
6A
EXHAUST SOUND CONTROL SPEAKER
6B
AMPLIFIER
61
AMPLIFIER
62
MEMORY (MAP INFORMATION)
45
4a
4b
46
4
CPU
44
WAVEFORM GENERATOR CIRCUIT (PHASE, AMPLITUDE CONTROL)
42a
RECTIFIER CIRCUIT
42
43a
43
BANDPASS FILTER
41
WAVEFORM RESHAPING CIRCUIT
3a
8a
8
5a
AIR FLOW METER
3
REFERENCE POSITION DETECTOR SENSOR
ENGINE ROTATING SPEED SENSOR
5

FIG. 3

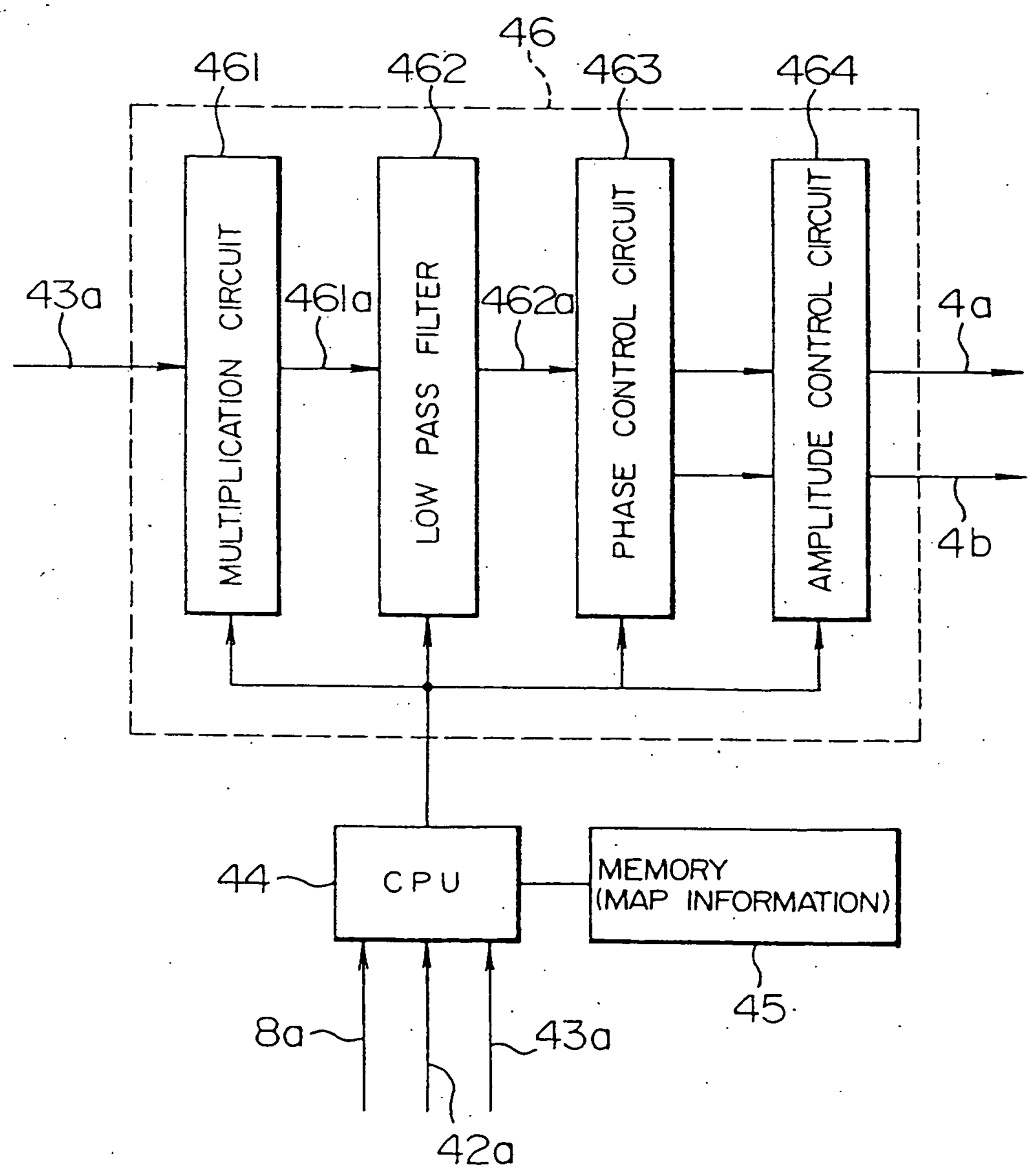

46
461
462
463
464
MULTIPLICATION CIRCUIT
LOW PASS FILTER
PHASE CONTROL CIRCUIT
AMPLITUDE CONTROL CIRCUIT
43a
461a
462a
4a
4b
44
CPU
MEMORY (MAP INFORMATION)
45
8a
43a
42a

FIG. 4

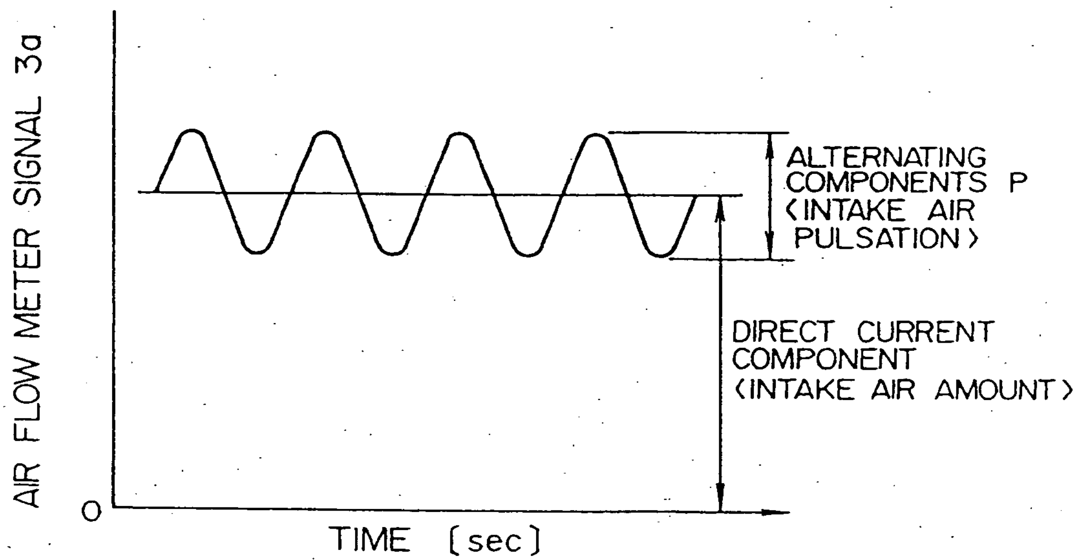

AIR FLOW METER SIGNAL 3a
ALTERNATING COMPONENTS P
⟨INTAKE AIR PULSATION⟩
DIRECT CURRENT COMPONENT
⟨INTAKE AIR AMOUNT⟩
0
TIME [sec]

FIG. 5

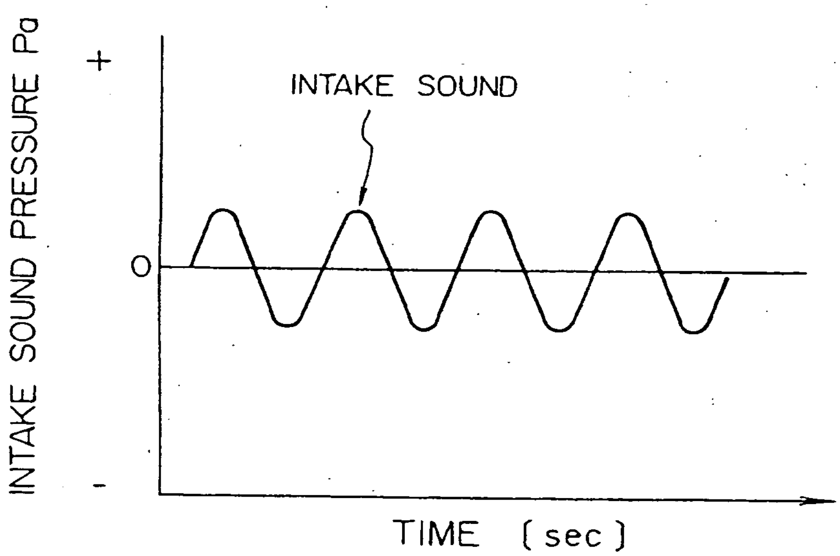

INTAKE SOUND PRESSURE Pa
+
0
-
INTAKE SOUND
TIME [sec]

FIG. 6

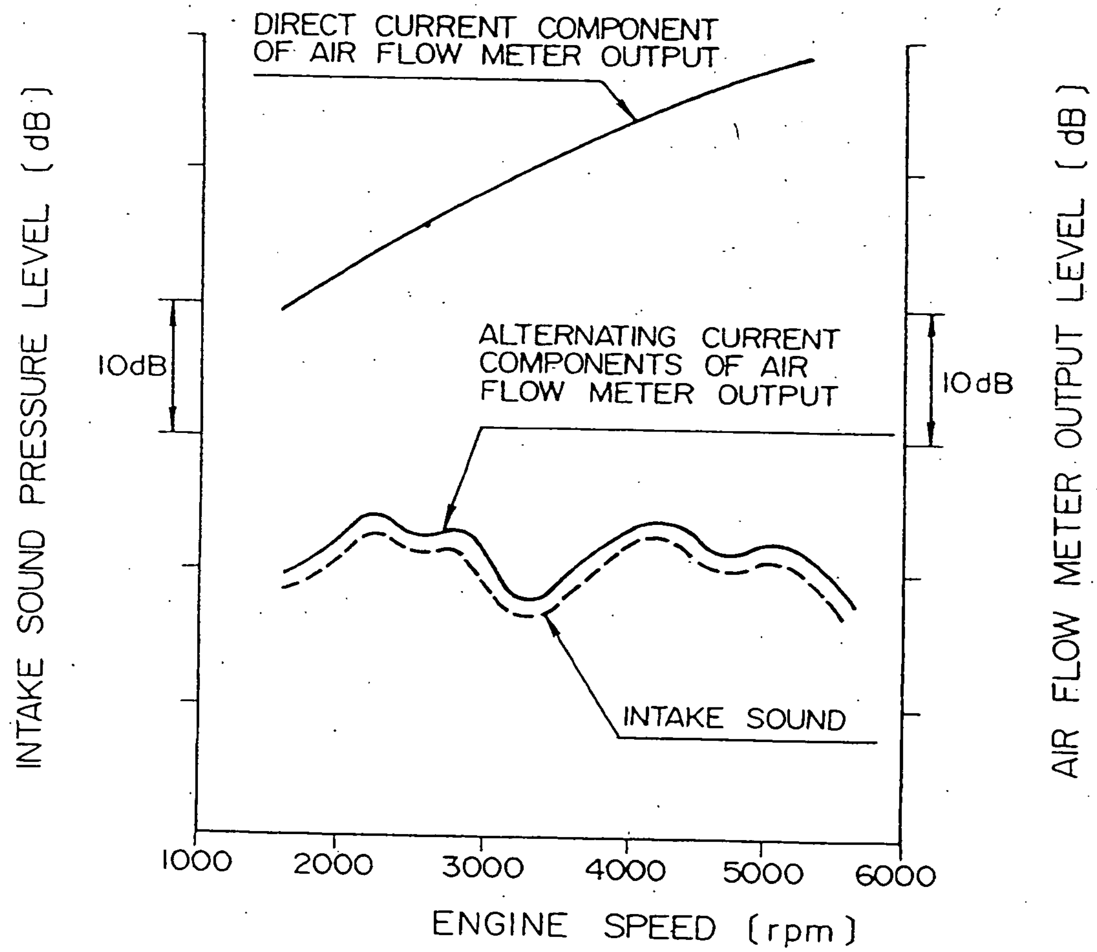

DIRECT CURRENT COMPONENT OF AIR FLOW METER OUTPUT
ALTERNATING CURRENT COMPONENTS OF AIR FLOW METER OUTPUT
INTAKE SOUND
10dB
10dB
INTAKE SOUND PRESSURE LEVEL (dB)
AIR FLOW METER OUTPUT LEVEL (dB)
1000
2000
3000
4000
5000
6000
ENGINE SPEED (rpm)

FIG. 7

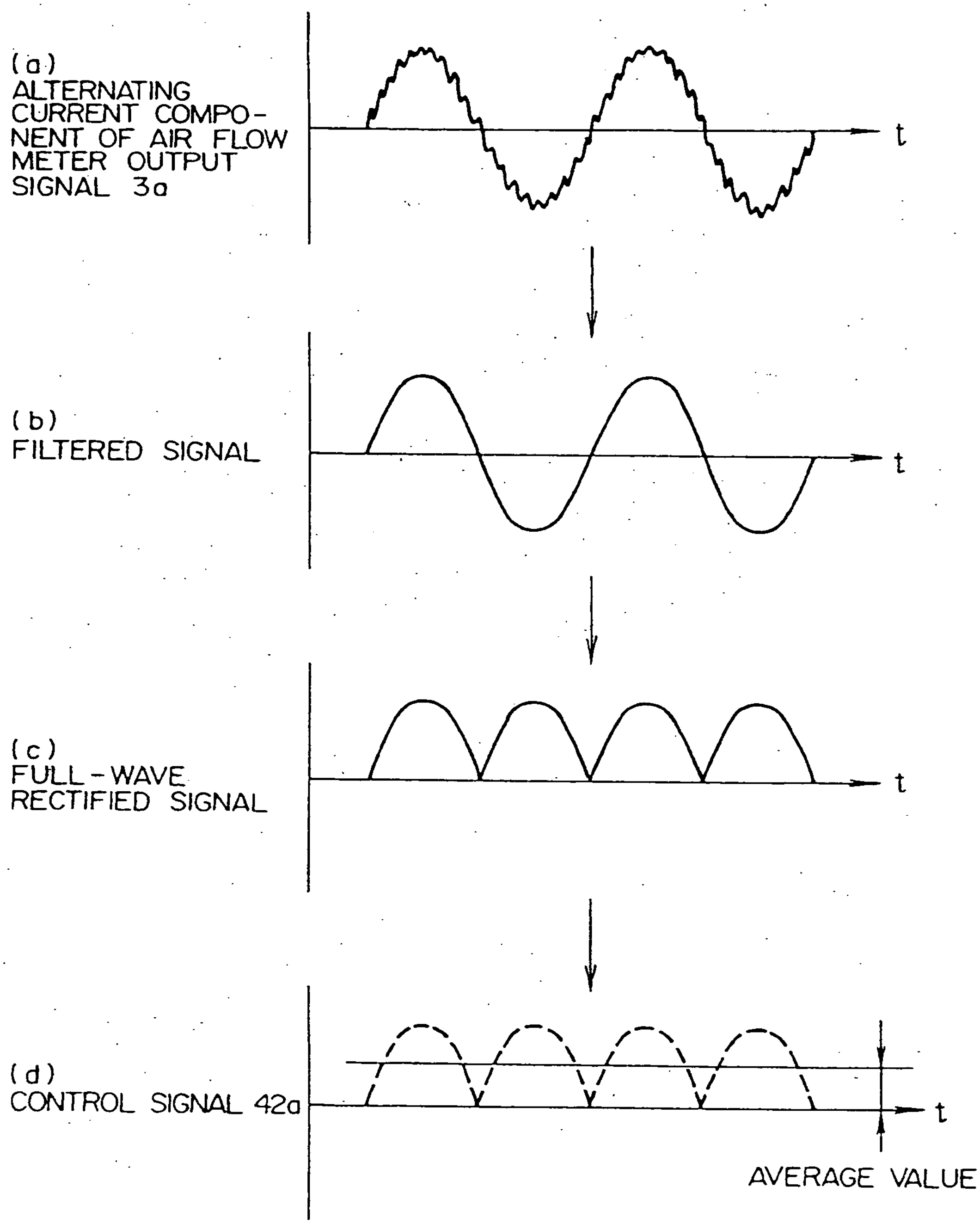

(a)
ALTERNATING CURRENT COMPONENT OF AIR FLOW METER OUTPUT SIGNAL 3a
t
(b)
FILTERED SIGNAL
t
(c)
FULL-WAVE RECTIFIED SIGNAL
t
(d)
CONTROL SIGNAL 42a
t
AVERAGE VALUE

FIG. 8

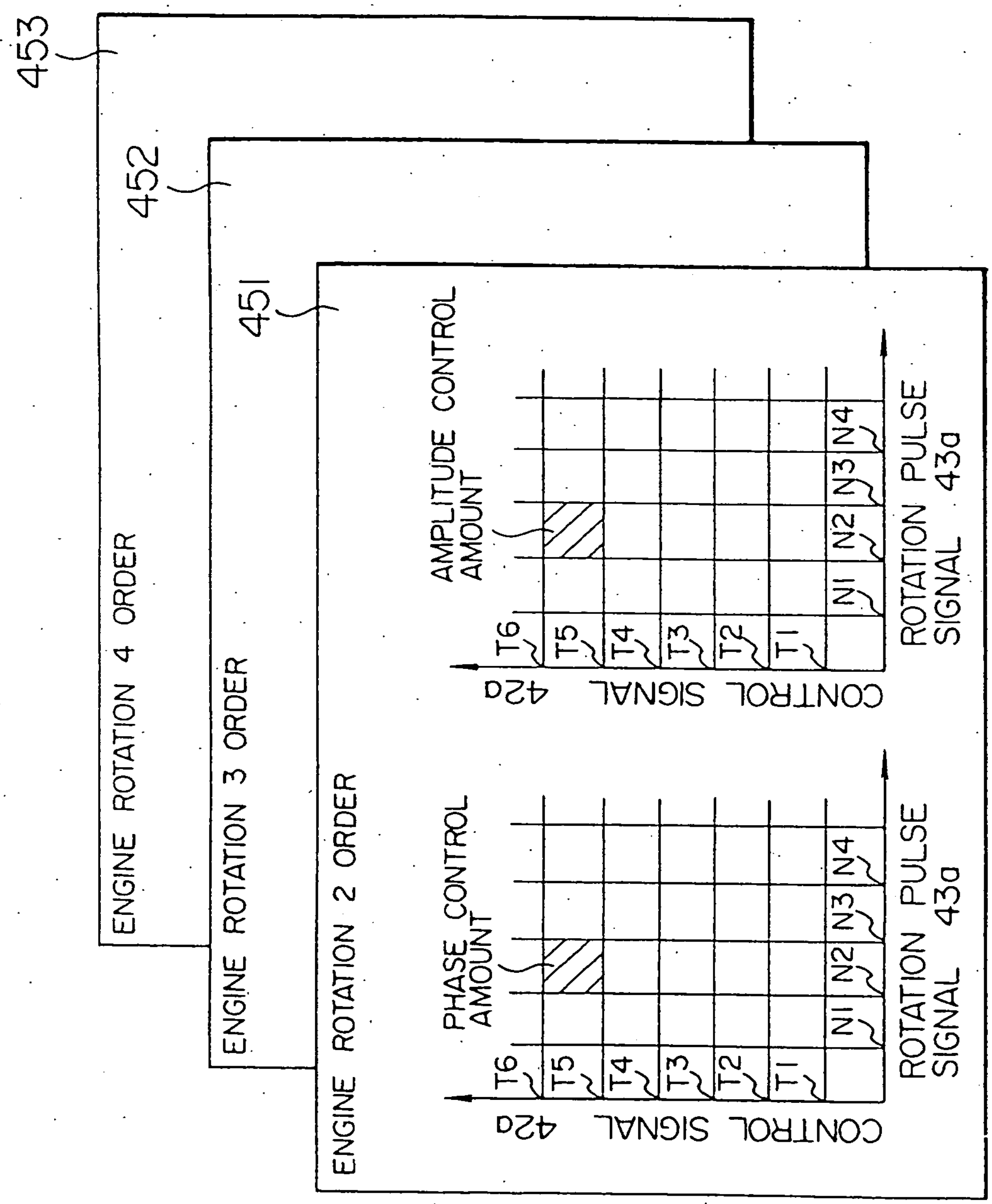

453
452
451
ENGINE ROTATION 4 ORDER
ENGINE ROTATION 3 ORDER
ENGINE ROTATION 2 ORDER
PHASE CONTROL AMOUNT
AMPLITUDE CONTROL AMOUNT
T6
T5
T4
T3
T2
T1
N1
N2
N3
N4
CONTROL SIGNAL 42a
ROTATION PULSE SIGNAL 43a
CONTROL SIGNAL 42a
ROTATION PULSE SIGNAL 43a

FIG. 9

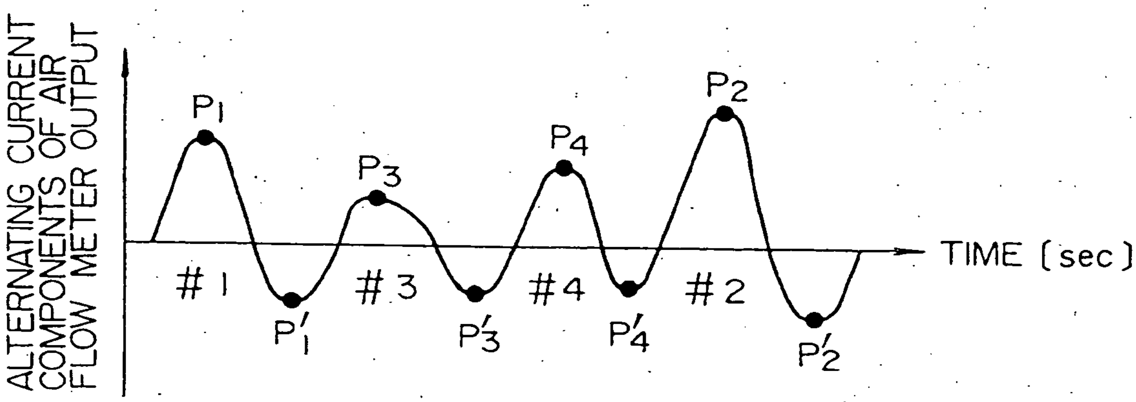

ALTERNATING CURRENT COMPONENTS OF AIR FLOW METER OUTPUT
P1
P3
P4
P2
#1
#3
#4
#2
P'1
P'3
P'4
P'2
TIME (sec)

FIG. 10

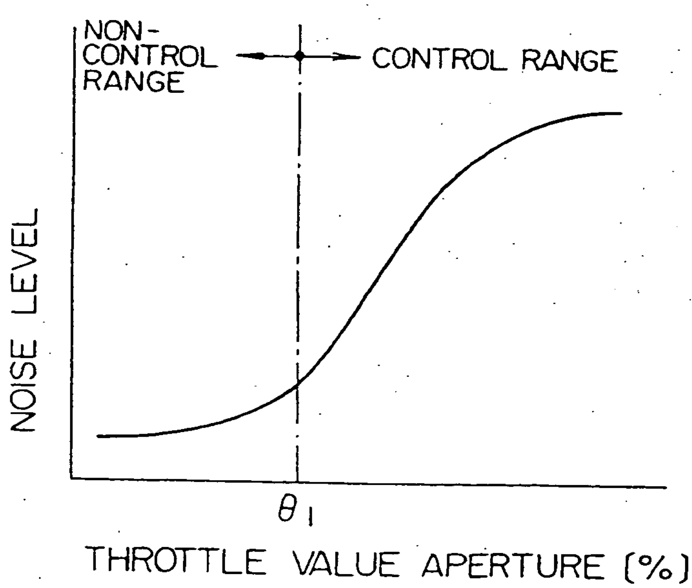
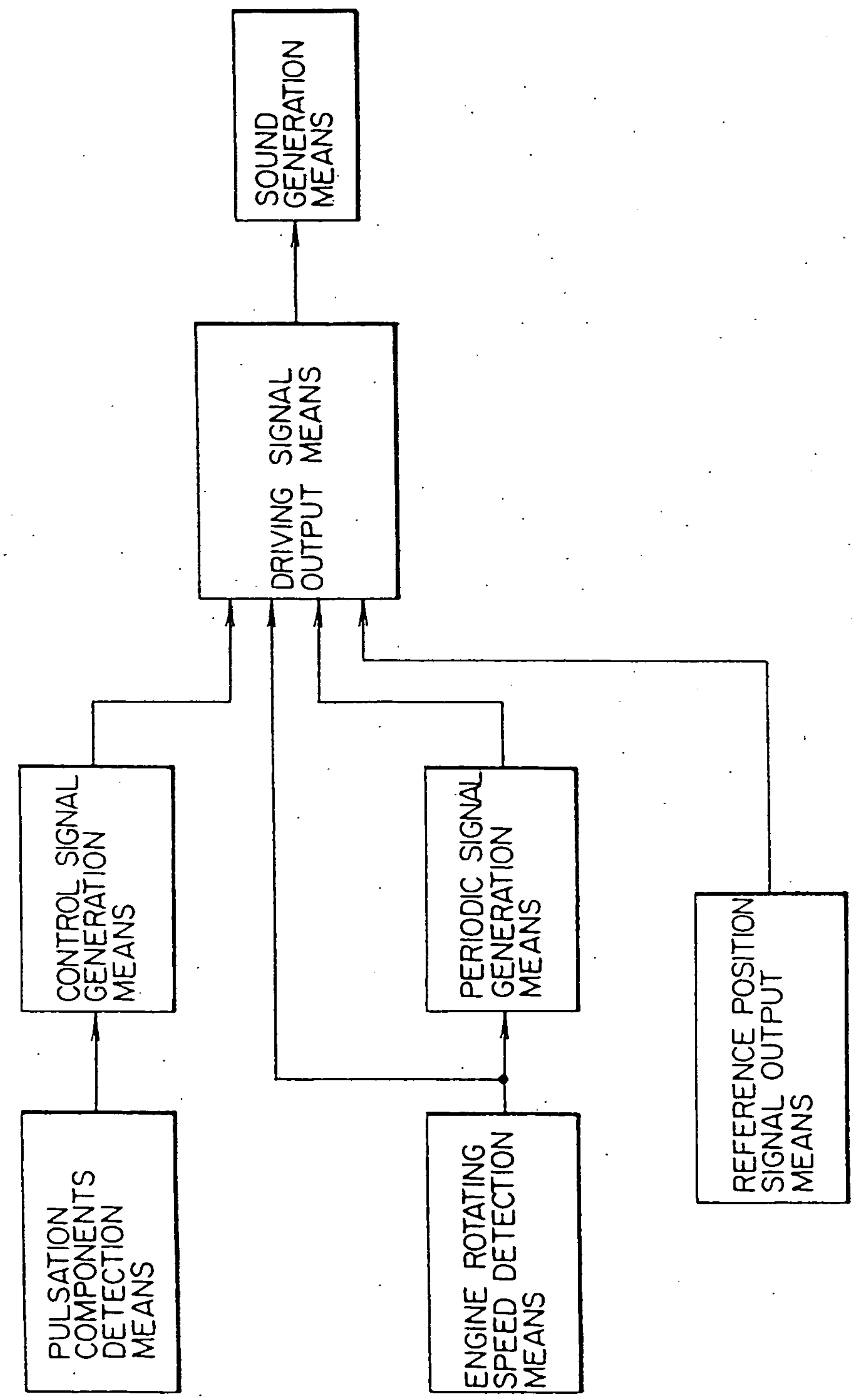

NON-CONTROL RANGE
CONTROL RANGE
NOISE LEVEL
θ1
THROTTLE VALUE APERTURE (%)

FIG. 11


SOUND GENERATION MEANS
DRIVING SIGNAL OUTPUT MEANS
CONTROL SIGNAL GENERATION MEANS
PERIODIC SIGNAL GENERATION MEANS
REFERENCE POSITION SIGNAL OUTPUT MEANS
PULSATION COMPONENTS DETECTION MEANS
ENGINE ROTATING SPEED DETECTION MEANS